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Haitian Oak (*Catalpa longissima* (Jacq.) Dum. Cours.)
Seed Orchards and Progeny Trials in Haiti: 1988–1996

by

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RESUME

Le chêne haitien (*Catalpa longissima*) est l'une des espèces de bois les plus populaires et les plus coûteux en Haïti. Son bois lustré et durable est utilisé dans l'ébénisterie, dans la construction de maisons et de bateaux et dans la sculpture. L'espèce est originaire des Grandes Antilles, mais elle se trouve aussi dans d'autres pays de la Caraïbe et d'Amérique Centrale où elle a été introduite comme un arbre ornemental pour son abondante production saisonnière de fleurs blanches voyantes et sa couronne élegante de fine texture. L'arbre est géré par les planteurs dans de riches plaines et ravines alluvialles, et est associé à des cultures comme la banane, le café, les arbres fruitiers, la patate et les haricots.

Un programme a été institué en 1989 dans le cadre du Projet Agroforesterie II financé par l'USAID pour entreprendre la sélection d'arbres supérieurs et installer une série de vergers et d'essais de leur progéniture à travers Haiti. Ce rapport résume la performance des vergers et des essais de progéniture de *C. longissima* établis sur 6 sites en Haïti durant la période 1988-1990.

Survie

Les essais de cette étude ont indiqué des taux de survie élevés, de 60% à 98%, avec une moyenne de 85% pour les 6 sites. Ces taux sont beaucoup plus élevés que ceux indiqués pour l'espèce par PADF et CARE, principalement à cause de la meilleure qualité des plantules et une gestion plus intensive du site. Les données recueillies suggèrent que ce n'est pas la qualité génétique *en soi* qui en est responsable, mais plutôt les facteurs environnementaux. Bien que des différences aient été observées entre les familles dans l'essai de progéniture à Lapila, elles ont été attribuées à l'âge de la plantule plutôt qu'à des variations entre les familles. Il ne faut pas s'attendre à ce que la sélection d'arbres supérieurs ait un effet significatif sur le taux de survie sur le terrain.

Croissance en hauteur

Les moyennes en hauteur ont varié de 1,5-6,1 m après 5 ans, les moyennes les plus basses et les plus élevées ayant été enregistrées sur deux sites dans la Plaine des Cayes. Des différences significatives entre les familles ont été observées dans l'essai de progéniture à Lapila et dans le verger de Terrier Rouge, après 5 ans. Dans les autres sites, les différences de croissance en hauteur entre les familles ont été insignifiantes ou nulles. Les différences ont ensuite diminué avec l'âge de l'arbre et ont largement varié entre les sites. Il n'a été détecté aucune tendance cohérente dans le classement des familles montrant que la correspondance d'un génotype supérieur aux conditions de site n'a pas d'effet sur la croissance en hauteur. Il existe peu de preuves pour affirmer que des avantages significatifs, en ce qui concerne la croissance en hauteur, peuvent être obtenus par la sélection d'arbres individuels.

La famille qui a accusé la croissance la plus lente dans le verger de Terrier Rouge provient d'un arbre supérieur sélectionné près du site, alors que les familles à croissance plus rapide sont issues d'arbres supérieurs sélectionnés dans le sud d'Haiti. La sélection d'une source de semences à proximité du site de plantation ne garantit pas l'adaptation et la vigueur exprimées à travers la croissance en hauteur.

Croissance en diamètre de tige

Généralement, il y a eu des différences plus importantes entre les familles pour la croissance en diamètre de tige que pour la croissance en hauteur. La moyenne de dhp du site (diamètre à 1,3 m) a été significative pour tous les sites, excepté Crocra. Les différences entre la famille la plus performante et la moyenne du site ont considérablement varié dépendant du site, de 8% à Laborde à 145% à Haut Camp. Il paraît que les différences sont liées aux conditions de site - plus les conditions de site sont extrêmes, plus l'écart entre les moyennes de famille est grand.

Volume marchand

De grandes différences dans le volume de bois, bois de sciage ou poteaux, ont été observées dans l'essai de progéniture de Laborde. Des différences entre les trois familles les plus performantes, avec une moyenne de 51 m^3 ha^{-1}, et la moyenne du site de 36 m^3 ha^{-1}, ont varié de 37% à 44%. En comparaison à la famille la moins productive, ces différences ont varié de 150% à 163%. Des caractéristiques qualitatives comme la forme de la tige et la hauteur utilisable, viendraient plutôt de l'hérédité, avec des avantages génétiques effectivement retenus à travers un programme de propagation végétative et de sélection récurrente.

Conclusions

Les vergers à graines et les essais rapportés ici représentent une ressource de valeur pour perpétuer l'espèce en Haïti et fournir des revenus aux planteurs. Les vergers contiennent la base génétique la plus large de l'espèce dans son habitat d'origine et représentent la meilleure opportunité jusqu'à présent de produire un mélange de semences largement apte à donner un matériel génétique supérieur aux petits planteurs. La reproduction végétative et aussi la sélection récurrente devraient être utilisées pour améliorer le rendement et la rentabilité de cette espèce populaire de bois, là où elle est déjà intégrée dans les systèmes de cultures en Haïti. La production et la vente de semences certifiées provenant des vergers, devraient aussi être explorées, particulièrement pour l'exportation vers des marchés extérieurs. *C. longissima* fait partie des ressources naturelles qui doivent être conservées par un investissement continu dans la conservation et l'amélioration génétiques à travers des vergers à graines et des tests de progéniture.

Recommandations

(1) **Groupes de Producteurs**. PLUS devrait avoir pour objectif de mettre à la disposition des planteurs la plupart du germoplasme amélioré sur des sites où le *C.longissima* croît le mieux et est déjà intégré dans les systèmes agroforestiers locaux - les plaines et ravines agricoles.

(2) **Rôle du Gouvernement.** Collaborer avec le Ministère de l'Agriculture dans la recherche de fonds pour la conservation et l'amélioration génétiques d'espèces d'importance économique. Mettre l'accent sur une stratégie à long terme et des bénéfices à court terme dont la production de semences certifiées, l'exportation et la commercialisation de semences, l'investissement du secteur public et privé dans la foresterie, la politique de ressources génétiques forestières, et la vulgarisation/éducation. Trouver des stimulants et appliquer une politique qui encourage les planteurs à gérer les arbres plantés, y compris *C. longissima.*

(3) **Promotion de l'espèce**. Il est nécessaire de mettre en place un système pour la production, la distribution et la commercialisation du chêne haitien. Les vergers et les essais de progéniture devraient être gérés par des individus entraînés, dédiés à l'amélioration des arbres. Il ne faudrait pas exclure la possibilité de produire des semences à partir des vergers pour la vente à des compagnies commerciales de semences ou directement aux pépinières à travers le monde.

(4) **Amélioration de l'arbre.** Les vergers et les essais existants devraient constituer la base d'une production et d'une distribution de semences aux planteurs en Haïti. Les semences améliorées issues des vergers devraient être distribuées aux planteurs à travers le pays en organisant une production efficace de plantules en pots.

(5) **Gestion de l'arbre au niveau de l'exploitation**. Des informations sur les procédures de propagation végétative devraient être disséminées avec le matériel génétique amélioré aux groupes de planteurs qui comprennent la gestion du *C. longissima*.

(6) **Adaptabilité à long terme**. Les essais de progéniture devraient être suivis pour résistance aux maladies, pestes, forme de l'arbre et autres paramètres qui affectent son impact économique potentiel pour les fermiers haïtiens pendant au moins la moitié du temps requis pour

produire du bois. L’analyse finale devrait se faire en termes de valeurs commerciales et se baser sur les volumes de recouvrement réel. Les sélections peuvent être faites dans les essais de progéniture tant au niveau de l’individu qu’à celui de la famille pour améliorer la qualité génétique des semences produites dans l’essai pour la production de la seconde génération.

(7) **Recherche appliquée**. Investiguer les moyens utilisés par les planteurs haïtiens pour sélectionner, propager et gérer *C. longissima* en tant que capital. Etudier les pratiques sylvicoles améliorées (propagation, éclaircie, taille et récolte) de *C. longissima*, spécifiques aux principaux modèles agroforestiers (i.e. lots boisés, plantations en bordure, arbres d’ombrage) rencontrés en Haïti.

(8) Développer des tables de volume pour une gamme plus large de diamètres que celle déterminée pour l’espèce par Ehrlich et al. (1986). Ces tables représentent un important outil de gestion, permettant une estimation précise des volumes tant au niveau de l’arbre individuel qu’au niveau du peuplement.

(9) Etudier la phénologie et la biologie de la pollinisation de l’espèce pour déterminer les stratégies de croisement et de sélection. Evaluer la situation de la conservation de l’espèce sur une base périodique.

SUMMARY

Haitian oak (*Catalpa longissima*) is one of the most popular and expensive woods in Haiti. It's lustrous and durable wood is used for cabinetry, boat and house construction, and sculptures. The species is native to the Greater Antilles, but it also found in other countries of the Caribbean and Central America where it has been introduced as an ornamental selected for the seasonal mass of showy, white flowers and the elegant, fine texture of its crown. The tree is managed by farmers in the rich alluvial plains and ravines, associated with food crops of plantain, coffee, fruit trees, sweet potatoes and beans.

A program was established in 1989 under the USAID-funded Agroforestry II project to begin selection of plus trees and establish their progeny in a series of orchards and progeny trials throughout Haiti. This report summarizes the performance of the *C. longissima* orchards and progeny trials established during 1988–1990 at 6 sites in Haiti.

Survival

The trials in this study exhibited high 5-year survival rates, ranging from 60–98% and averaging 85% on 6 sites. These rates are much higher than those reported for the species by PADF and CARE, primarily due to better seedling quality and more intensive site management. The data suggest that it is not genetic quality *per se* that is responsible for better seedling quality, but rather environmental factors. Though differences were observed among families at the Lapila progeny trial, these differences are attributed to seedling age rather than family differences. It should not be expected that selection of plus trees will have a significant effect on field survival.

Height Growth

Site means ranged from 1.5–6.1 m after 5 years, highest and lowest means occurring on two sites in the Cayes Plain. Differences among families were statistically significant at the Lapila progeny trial and the Terrier Rouge orchard after 5 years. The remaining sites showed either weak or no differences in height growth among families. If differences were shown, these differences decreased with tree age and ranged widely across sites. There was no consistent pattern in family ranks showing that matching of a superior genotype with site conditions is not effective for height growth. There is little evidence that significant gains in height growth can be achieved by selecting at the individual tree level.

The slowest growing family at the Terrier Rouge orchard originated from a plus tree selected near the site, whereas the fastest growing families originated from plus trees selected in southern Haiti. Proximity of seed source to planting site does not insure adaptability and vigor as indicated by height growth.

Stem Diameter Growth

Overall, there were greater differences among families for stem diameter growth than for height growth. Site dbh (diameter at 1.3 m) means ranged from 1.6–11.1 cm after 5 years. The variation among family means for dbh (diameter at 1.3 m) was significant at all sites except Crocra. Differences between the top family and the site mean varied widely depending on site, from 8% at Laborde to 145% at Haut Camp. Differences appeared to be related to site conditions – more extreme site conditions resulted in a greater spread among family means.

Merchantable Volume

Large differences in wood volume considered for saw lumber or poles was exhibited at the Laborde progeny trial. Differences between the top three families, averaging 51 m^3 ha^{-1}, and the site mean of 36 m^3 ha^{-1} ranged from 37–44%. Compared to the least productive family, these differences ranged from 150–163%. Qualitative traits such as stem form and usable height are more likely to be inherited, with the genetic gains effectively captured through a program of vegetative propagation and recurrent selection.

Conclusions

The seed orchards and trials reported here represent a valuable resource for perpetuating the species in Haiti and providing income to farmers. The orchards contain the broadest genetic base of the species in its native range and have the best chance to date of producing a seed mix that is broadly adapted for providing superior genetic material to small farmers. Both vegetative reproduction and recurrent selection should be used to improve the yield and profitability of this popular tree species on site where farmers have already integrated the tree in their cropping patterns. Production and sale of certified seed from the orchards should also be explored, particularly for expanded markets abroad. *C. longissima* is part of the natural resource base that must be conserved through continued investment in both genetic conservation and improvement with seed orchards and progeny testing.

Recommendations

(1) **Producer Groups.** PLUS should target most of the improved germplasm to farmers with sites where *C. longissima* grows best and is already integrated into local agroforestry systems – the agricultural plains and ravines.

(2) **Role of Government.** Collaborate with the Ministry of Agriculture in seeking funds for genetic conservation and improvement of economically important tree species. Focus on a long term strategy and short term benefits that include certified seed production, seed export and marketing, public and private sector forestry investment, forest genetic resource policy and extension education. Determine incentives and enforce policy that encourages farmers to manage tree crops, including *C. longissima*.

(3) **Species Awareness.** A system needs to be put in place for production, distribution and marketing of Haitian oak. The orchards and progeny trials must be managed by trained individuals committed to tree improvement. Seed production from the orchards should not be overlooked as a commercial product to be marketed through seed companies or directly to nurseries worldwide.

(4) **Tree Improvement.** The existing orchards and trials should form the basis of a seed production and distribution to farmers in Haiti. Improved seed from the orchards should be channelled to farmers nationwide through an efficient production of containerized seedlings.

(5) **Farm-Level Tree Management.** Information on vegetative propagation procedures should be disseminated along with improved genetic material to farmer groups who understand the management of *C. longissima*.

(6) **Long Term Adaptability.** The progeny trials should be monitored for disease resistance, pests, tree form and other parameters that affect its potential economic impact to Haitian farmers for at least half the time required to produce lumber. The final analysis should be in terms of market values and should be based on actual recovery volumes. Selections can be made in the progeny trials at both the individual and family levels to improve the genetic quality of seed produced from the trial for second generation production.

(7) **Applied Research.** Determine ways that Haitian farmers select, propagate and manage *C. longissima* as an asset. Study improved silvicultural practices (propagation, thinning, pruning and harvesting) of *C. longissima* specific to the major agroforestry models (i.e., wood lots, boundary plantings, shade trees) in Haiti.

(8) Develop volume tables for a larger diameter range than that determined for the species by Ehrlich et al. (1986). These tables are an important management tool, allowing for an accurate estimation of volume at both the individual and stand levels.

9) Study phenology and pollination biology of species for breeding and selection strategies. Determine the conservation status of the species on a periodic basis.

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ACRONYMS

AOP	Agroforestry Outreach Project (1981–1987)
AF II	Agroforestry II Project (1988–1991)
AU	Auburn University
IRG	International Resources Group, Ltd.
OFI	Oxford Forestry Institute
PADF	Pan American Development Foundation
PLUS	Productive Land Use System project (1992–present)
SECID	South East Consortium for International Development
USAID	United States Agency for International Development

INTRODUCTION

Catalpa longissima (Jacq.) Dum. Cours. is one of the most popular woods in Haiti. Known as Haitian oak, it's lustrous and durable wood is used for cabinetry, boat and house construction, and sculptures. The market value of premier quality wood is higher than mahogany in Haiti (Barkley, 1984), one of the primary incentives for its cultivation. The species is not a true termperate oak (*Quercus*), but a member of the Bignoniace family, native to Hispaniola and Jamaica. The species has been naturalized in other countries of the Caribbean and Central America, selected as an ornamental for its seasonal mass of showy, white flowers and the elegant, fine texture of the crown. It is managed in association with food crops along the alluvial flood plains and in ravines where agricultural productivity is high. Key features that contribute to its versatility as an agroforestry species includes its high wood value, coppicing ability, light to medium shade, ease in vegetative propagation, favorable response to pruning, and rapid growth. Additional information on *C. longissima* can be found in Francis (1992) and Timyan (1996).

Because of its economic importance as a tree species and its demand by a large number of Haitian farmers, a tree improvement program was initiated with *C. longissima* by IRG during the USAID-funded Agroforestry II project (1987–1989) and continued by SECID/Auburn University from 1990–1996. A total of 127 plus trees were selected in Haiti for desirable characteristics such as stem form, size and merchantable volume. The progeny of 52 plus trees were established in seed orchards to produce improved seed for distribution to Haitian farmers. Progeny trials were established to examine the genetic variation among families for survival, height, stem diameters and merchantable wood volume. This report is a preliminary summary of the *C. longissima* orchards and progeny trials after 5 years.

OBJECTIVES

The major objective of the *C. longissima* trials in Haiti are to improve the genetic quality of *C. longissima* germ plasm distributed throughout Haiti. Specific objectives include:

(1) Broaden the genetic base of *C. longissima* in Haiti by collecting seed from superior phenotypes and establishing their progeny in a series of orchards and progeny trials;

(2) Measure the genetic variation of *C. longissima* families for differences in survival, growth parameters (height, dbh (diameter at 1.3 m) and basal diameter) and merchantable wood yields.

(3) Determine the *C. longissima* genotypes that exhibit broad adaptability in Haiti and optimize economic returns to the Haitian farmer.

(4) Improve the genetic quality of *C. longissima* by roguing the seed orchards of inferior genotypes and distributing improved seed throughout Haiti through the USAID PLUS project and other reforestation programs.

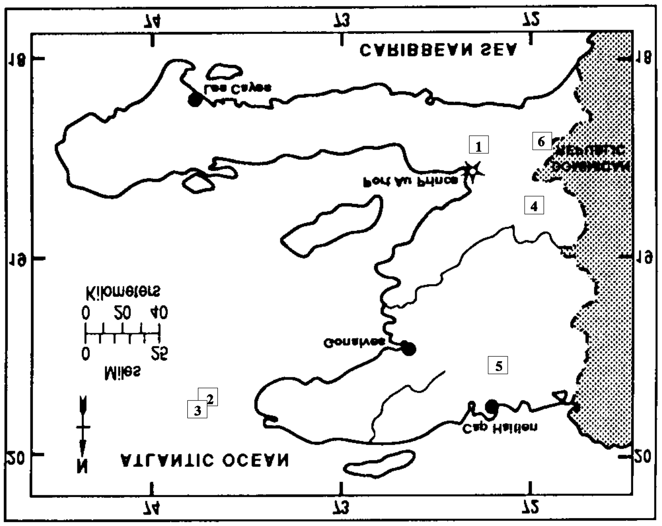

Figure 1. Location of the *C. longissima* trials in Haiti. 1 = Crocra, 2 = Haut Camp, 3 = Laborde, 4 = Lapila, 5 = Roche Blanche, 6 = Terrier Rouge.

MATERIAL AND METHODS

Study Sites

The trial sites represent a diverse range of edaphic and physiographic conditions found in the low-elevation regions of Haiti (**Figure 1; Table 1**). A major consideration of site selection

Table 1. Site characteristics of the *C. longissima* trials in Haiti.

SITE PARAMETERS	ROCHE BLANCHE	HAUT CAMP	CROCRA	TERRIER ROUGE	LABORDE	LAPILA
LATITUDE	18º 32' N	19º 25' N	19º 41' N	19o 39' N	18o 17'	19o 18'
LONGITUDE	72º 11' W	73º 20' W	72º 17' W	71o 58' W	73o 48' W	72o 06' W
ALTITUDE (m)	100	350	20	40	75	350
ANNUAL RAINFALL	950	2150	2057	885	1800	1250
HOLRIDGE LIFE ZONE	Dry Forest	Moist Forest	Moist Forest	Dry Forest	Moist Forest	Moist Forest
SLOPE (%)	0–1	80–90	0–2	0–1	5–10	0–2
SOIL pH	8.2-8.3	6.7	6.3	NA	8.2-8.5	7.3
% CLAY	17.5	10	45	NA	12.5-30	10
SOIL P (ppm)	55	6	8	NA	3-10	9-17
% ORGANIC MATTER	2.6 - 2.7	3.8	3.5	NA	3.5-6.5	4.8
PARENT MATERIAL	Calcareous	Calcareous	Calcareous	NA	Calcareous	Calcareous

was land availability, relative ease of access, and potential of full cooperation between SECID/AU and landowners with land security. Optimal site matching and land use history are important factors in the success of any trial, though these were considered less a priority at this preliminary stage of genetic testing. Table 1 summarize the ecological characteristics of the study sites.

Seed Collection

Seed for the trial was harvested from plus trees selected for a combination of superior form, vigor and size (**Annex 1**). The plus trees were selected throughout regions of Haiti where *C. longissima* was being harvested for lumber and sizeable stands of the species were available for a sufficient selection intensity. A total of 127 plus trees were selected throughout Haiti between 1988–1991 at which time field operations were suspended by USAID due to the coup d'état and the ensuing economic embargo. The seed of 52 trees, selected during the 1988–1989 interval, were propagated and established in the trials that are included in this report. The numbers assigned to the mother trees refer to the same numbers assigned to the families in the trials. In addition to the plus tree collections, bulked seed lots harvested for the PADF containerized nurseries were included in the Roche Blanche orchard to broaden the genetic base to 54 genotypes – the largest collection in Haiti, if not the world, for this species.

All seed harvested from the plus trees was assumed to be outcrossed with neighboring trees. If trees were selected within a stand area, care was taken to select trees with a minimum distance of 100 m apart. *Catalpa* species are self-incompatible and pollinated by diverse types of insects, mostly bees and moths (Gentry, 1974; Stephensen, 1982).

Nursery Phase

The seedlings were raised at a private nursery owned and managed by Operation Double Harvest (ODH) at Roche Blanche, located 7 km from Croix-des-Bouquets. The seedlings were propagated in Winstrip containers, a plastic container tray developed by Van Wingerden International. The trays consisted of 128 cells, each approximately 130 ml in volume, designed for superior development of the root plug and efficient handling of the seedlings to the planting site. The potting medium was prepared at ODH, known as "Haiti Mix," utilizing 75% bagasse, 15% rice hulls, 15% clayey loam and fertilizer. All seed collections were propagated as fresh seed without treatment, following procedures outlined in Josiah (1989).

Each family accession was individually handled to insure proper labeling. Approximately 500 seedlings were prepared per family. In general, the seedlings were propagated under shade for 6–8 weeks prior to transferring them to full sun. Foliar fertilizers and overhead irrigation were applied for optimum growth. A period of reduced water and fertilization in full sun was applied for a period of 4–6 weeks to ensure that the seedlings were properly hardened off prior to field planting.

Experimental Design and Trial Establishment

This study includes only those trials that were continued for a period of 5 years. A number of *C. longissima* trials were established but discontinued for various reasons. A progeny trial in the Grand Anse (Gélin) was abandoned because of its geographical isolation and logistical difficulties from Port-au-Prince. The orchards established in the Northwest (Bombard) and the Central Plateau (Marmont) were eliminated after several years of very poor growth. Three progeny trials (Osédi, Madame Si, Labordette) were discontinued after a decision by the landowners to convert the trials back to traditional cropping activities. The La Jeune progeny trial in the Central Plateau grew very well during the first 2 years, but was severely damaged by fire set to the land in preparation of a garden nearby in 1994. The trial was abandoned for research purposes at that time.

The preparation of the trial sites differed depending on the site conditions and proposed management of the trials, some of which were intercropped with annual crops during the first 2 growing seasons. At the Laborde and Terrier Rouge trials, the seedlings were planted after the land was prepared and a crop was sown and weeded thereafter. The Crocra, Haut Camp, Lapila and Roche Blanche trials were not intercropped. In both cases, the sites were clear-weeded and holes dug prior to the onset of the rainy season. Seedlings were planted when soil moisture conditions approached saturation during the first series of rains. The trials were replanted with seedlings about a month following establishment. Weed management was supervised by the IRG/SECID team, including contracts to the landowner in cases that the trials were not intercropped or required weeding during alternate periods between cropping seasons.

The Roche Blanche orchard was expanded by eliminating every second and third row of the original trees and replacing them with a completely different set of 36 families. Holes were dug in between the stumps of the eliminated trees and line weeded. The stumps were left to rot *in situ*.

Table 2 summarizes the trial information at each site. The orchards were established as single-tree family plots in a systematic design with family plots isolated by 2 non-related family plots (Giertychm, 1975). The number of replications per family ranged from 26–27. The progeny trials were complete randomized block designs, with 6-tree row plots and 9 replications. All trees within plot were measured throughout the study period.

Table 2. Experimental design of *Catalpa longissima* trials in this study.

	LABORDE	TERRIER ROUGE	ROCHE BLANCHE 1 & 2	CROCRA	LAPILA	HAUT CAMP
ESTABLISHMENT DATE	Mar 22, 1989	Nov 15, 1990	Oct 17, 1988; Mar 15, 1990	Dec 08, 1990	May 18, 1989	March 16, 1989
NO. OF FAMILIES	14	18	18 + 36	8	23	24
REPLICATIONS	9	9	26	9	9	27
TREES/PLOT	6	6	1	6	6	1
SPACING (m)	2.0 x 3.0	2.0 x 2.0	2.5 x 3.1	2.0 x 2.0	1.6 x 2.5	2.0 x 3.0

Measured Variables and Observations

The original measurement schedule was 12, 36 and 60 months after the establishment of the orchards and progeny trials. This schedule for the most part was followed, though some measurement periods were missed because of project irregularities associated with political instability, changes in project research orientation and the economic embargo that endured from 1991–1994. The following parameters were measured at each measurement interval.

1) Survival, in %, at 12, 36 and 60 months.

2) Total height, in meters, measured with a telescopic height pole at 12, 36 and 60 months.

3) Diameter at 1.30 m height, in cm, measured with a cloth diameter tape at 36 and 60 months. This diameter is given as dbh.

4) Basal or stump diameter at 0.1 m above ground, in cm, measured with a cloth diameter tape at 60 months. This diameter is given as $D_{0.1}$.

Additionally, the status of each tree was evaluated and assigned a code that corresponded to a range of possible factors affecting its status. Any tree that was damaged due to non-natural causes, mostly human or animal damage, was eliminated from the data used to determine height and diameter statistics.

Statistical Analysis

Field data was entered into the computer using a Lotus 123 spreadsheet. Merchantable volume was calculated for statistical analyses by multiplying stem height by dbh^2 (Butterfield, 1996). Survival data was transformed to the square root of the arc sine for analysis of variance and mean separation tests, according to procedures outlined in Steele and Torrie (1980). Analysis of variance and means comparison by the Waller-Duncan k-ratio Test (a = 0.05) were calculated to detect differences and rank genotypes with SAS 6.04 (SAS, 1988). Plot means were used for both the ANOVA and range tests.

RESULTS AND DISCUSSION

Plus Tree Selections

The range of stem diameters of the mother trees of the progeny in the trials is typical of the range found in Haiti. The minimum diameter of trees sawn for lumber is roughly 25 cm and most of the trees were above this limit. Exceptionally formed trees below the limit were selected as well, and would be considered for house construction as framing timbers. The largest trees were found in the Cap Haitien area with dbh (diameter at 1.3 m) commonly over 0.5 m. These trees were owned by the larger landowners of the region. Heights averaged nearly 20 m, with the tallest individuals measuring 26–27 m. Crown widths of plus trees found on small farm lots were typically less than their natural forms, since the tree is pruned back to the main stem to manage light conditions to understory crops and concentrate wood production along the stem axis. Many of the larger trees had been left to develop their natural form. Crown diameters for these trees reached up to 14 m. Stem height, perhaps the most important selection criteria in terms of quality and corresponding wood value, averaged 12 m, ranging from 6 m to several trees that were managed as clear boles to the height of the tree (e.g., 22 m).

The availability of seed at the time of tree selection was an important determinant for the families that were finally established in the trials. Many of the locations were difficult to re-visit and a number of plus trees were never harvested because of this reason. About half of the number of plus trees were harvested at the time of selection. This proportion is higher than that of the normal population because a fruiting tree was more likely to be selected than a non-fruiting individual. Most of the trees were harvested during the summer period (May–September) with a smaller number between November–January.

Survival

Annex 2 provides a summary of the survival data by family and trial. Five-year survival of *C. longissima* in the orchards and progeny trials far exceeded the species' average performance at the farmer level (Smucker and Timyan, 1995). This was due to a combination of factors, notably better seedling quality and tree management. The latter included a post-establishment replant (within 2–4 weeks), timely weeding, supervised intercropping activities, and the elimination of problematic sites. Many of these factors are difficult for the small farmer in Haiti to control.

The highest survival rates were achieved in the humid Cayes Plain in southwestern Haiti. Laborde and Haut Camp exhibited survival rates of 98% and 91%, respectively. The other sites achieved slightly lower survival rates corresponding to the drier site conditions of those trials. However the narrow range of the survival means (85–87%) at those sites are indicative of the relative stability of the species across sites. This would appear to be in conflict with the variability of the species' performance as reported in the PADF and CARE reports, as well as scientific studies (Campbell, 1994). However, low survival rates of the *C. longissima* is rarely the fault of the species as much as it is inadequate silvicultural knowledge and improper management on the part of the planter, especially poor site selection or neglect, and poor seedling quality. It is a hardy species and survives well if proper attention is targeted to site-specific requirements.

The three progeny trials considered in this report were analyzed for differences in survival among the *C. longissima* families tested at each site. The families did not test significant at the two sites (Crocra and Laborde) where the number of families represented in the trial were smaller and seedling age among family accessions was similar. The Lapila site, also among the least favorable site for *C. longissima*, showed differences among families at the 0.0001 probability level. However, such differences are probably not genetic differences *per se* but differences attributed to seedling age. The lowest surviving families (131, 132 and 146) were 5-month seedlings, while the rest of the seedling stock were propagated for 8 months prior to out planting. Though the younger seedlings averaged the same age as those being delivered by PADF in the Central Plateau during the same period, the harsh site conditions of Lapila actually required higher quality seedlings. When these 3 families were eliminated from the analyses, there were no survival differences shown among the remaining families. The probability level of the F-test was 0.2478.

There is weak evidence that the genetic variation that occurs among *C. longissima* trees, either at the family or stand level, significantly effects their survival rate in the field. Family ranks change with different sites in near random fashion. Other factors, such as seedling quality and site conditions, play a far more important role.

Height Growth

Height growth is a good indicator of a tree's vigor and adaptability to site quality differences that exist in Haiti. The most dramatic differences were revealed among sites rather than within site, indicating that environmental differences among sites causes most of the variation observed in the height growth of *C. longissima*. Mean heights, after 5 years, ranged from 1.5 m at Haut Camp to 6.1 m at Laborde. Though these two sites are separated by only 8 km, the Haut Camp site has extremely shallow, rocky soils with a 85% slope. Height growth at Roche Blanche was comparable to Laborde (5.9 m), while the other sites exhibited much slower growth rates, ranging from 1.6–2.7 m. Under normal circumstances, *C. longissima* would be eliminated from such sites because of the slow growth. The much slower growth of Roche Blanche 2, occupying the same site as Roche Blanche 1, was probably a result of root competition and shade by the orchard trees that were established 18 months earlier and weed competition during the establishment period.

In general, differences in height growth among families decreased with tree age. Statistical differences were detected among families after 5 years for Terrier Rouge and Lapila. Neither site is particularly well-suited for *C. longissima.* The fastest growing trials, Roche Blanche and Laborde, did not exhibit any difference among families at the 0.05 level at either 3 or 5 years. The other trials either showed no difference among families throughout the trial period, or if differences were shown, these occurred only at the 1-year stage.

The most significant differences in height growth among families was shown at the Terrier Rouge orchard. The top height was achieved by a family (160) originating near Grand Goâve. The mean height of this family, 3.4 m, was significantly different from the mean heights of families 132, 174 and 122 and 32% greater than the site average. It is noteworthy that 122 originated from a plus tree selected near the orchard site and nearer than any of the other plus trees. Differences were shown between this family and the top 4 families originating from the southern peninsula of Haiti – Leogâne, Jacmel and Grand Goâve. If the Terrier Rouge orchard is any evidence of what may occur on a farmer's site, then the variation shown is a helpful reminder that proximity of a seed source to the planting site does not necessarily guarantee the best performance.

The differences among families at Lapila were less significant than at Terrier Rouge. Height growth ranged from 1.3–2.2 m after 5 years with an average of 1.6 m. The top family, 149, showed a height advantage of 34% over the site mean and 69% greater than the slowest growing families. The mother trees of the top families originated from diverse regions of Haiti – Lascahobas, Petite Rivière de Nippes, Leogâne, and Mirebalais. Several of the least productive families were also from the Leogâne area.

Family rank is hardly consistent across trial sites, though most of the families were insufficiently tested for rigorous cross site comparisons. There is no indication that any one stand or region of Haiti was superior to any other in terms of producing superior height growth. If any genetic differences are shown, most of the variation is environmental, with a small portion attributed to variation at the individual tree level, but not at the stand or population level. Growth characteristics are generally considered less inherited than qualitative characteristics, being influenced by a number of complex factors that are not easily determined at the genetic level (Zobel and Talbert, 1984).

Major site limitations may be inhibiting the *C. longissima* families to express their true genetic variation at several sites not typical of the well-drained alluvial soils that the species is adapted to. Crocra is a poorly drained vertisol; Lapila is a droughty, shallow soil with calcareous tuff very near the surface; Haut Camp is extremely rocky and steep. The results from these trials should be interpreted cautiously, particularly since *C. longissima* does not show any economic promise on such sites.

Stem Diameter Growth

The time required to achieve a minimum stem diameter is an important trait for tree species such as *C. longissima* that are managed for their wood volume. The variation shown among families more or less correlates with the differences shown for height growth, though differences in ranks are expected because of differences in tree form that are associated with age differences and genotype. The data should be interpreted cautiously, since early trends do not necessarily predict differences at harvest time. It is recommended to evaluate genotype differences in traits at one-half the rotation age of the site (Zobel and Talbert, 1984). If 40 years is a typical rotation age in Haiti, then 5-year results are hardly sufficient to determine differences with any degree of certainty.

Overall, there was greater differences shown among stem diameters than for height during this early assessment period. Crocra did not show any differences in stem diameter at the 4- and 5-year measurement period. Laborde showed differences among families for dbh (diameter at 1.3 m) after 3 years and for basal diameter after 5 years. The top families at Laborde achieved 7–10% greater stem diameter growth than the site average and about 30% greater diameter growth than the least productive genotypes. The percentage differences at Lapila were greater, mainly because the stem diameters used for calculating the percentages were smaller. The difference between the top families and the site average was about 31%. Differences between the top families and the least productive families approached 70%.

All three orchards showed statistical differences after 5 years, with Terrier Rouge exhibiting the greatest variation among families. The top family, 160, exhibited a 60% greater dbh (diameter at 1.3 m) growth than the site average and 172% greater than the worst performing family, 122. Though the variance attributed to genotype at Haut Camp was less significant, the spread between the family means was greater. The Roche Blanche showed a comparable range of differences as Terrier Rouge, with the top family, 169, achieving 61% greater growth than the least productive family, 159, and 14% greater growth than the site average.

As with height growth, family ranks vary according to site. Though the genetic variation within *C. longissima* appears to be large enough to justify selection for increased productivity, it would be very difficult to make an *a priori* match of genotype to site based on the data in this report. The only way to confirm the genetic worth of a given genotype for a particular site would be to conduct broad a genetic test on a given site, capture the genetic gain through vegetative propagation and gradually increase wood productivity through recurrent selections. This would only be possible under conditions of secure land *and* tree tenure, which may be possible for only a limited number of Haitians.

Merchantable Volume

Any difference detected among *C. longissima* progeny with respect to lumber volume is important when assessing the potential economic impact of an improved genotype. Lumber is the most valuable harvest of *C. longissima* and the reason why most Haitians would plant the species. Only one progeny trial, Laborde, was evaluated for stem height and its corresponding merchantable volume. The other trials were not measured, either because they were not being managed for wood volume or designed to test for genetic differences (i.e., seed orchards) or because their growth was insufficient for meaningful conclusions (Crocra and Lapila).

Table 3 summarizes the estimated wood volumes by family. The highest yields were exhibited by 117, 104 and 105, averaging 53, 52 and 50 $m^3 ha^{-1}$, respectively. These yields range from 37–44% greater than the site mean for all genotypes combined and 150–163% greater than the least productive family, 169. The differences among families are largely attributed to the differences in usable stem heights, a qualitative characteristic that combines both form and height at which primary forking occurs. These 3 families account for about half of the individuals in the top decile. In terms of merchantable volume, the top 10% of the individuals represent 40% of the stand volume and the three families account for a disproportionate third of this volume. Differences in economic value should be greater since larger individual stem volumes are more profitable. The genetic variation among families at Laborde indicates a potential to improve economic productivity if proper steps are made in genotype selection.

Qualitative differences have been shown to be more highly heritable than growth differences (Zobel and Talbert, 1984). It is highly likely that if genetic gain were captured through vegetative propagation, significant improvement in stand production of lumber would be achieved under similar site conditions. Though a few farmers use vegetative techniques with *C. longissima*, it is not likely that they are using superior genetic material that could significantly increase their yields of high-quality lumber. Heritabilities for qualitative characteristics are of sufficiently large to justify a tree improvement program. An economic analysis that incorporates the full cost of a tree improvement program with species such as *C. longissima* has not been conducted. However, tree improvement should not be overlooked, as improved genetic quality can play an important role in increasing the income of small farmers.

Table 3. Wood volume estimates of *C. longissima* families after 5 years at Laborde. Means followed by the same letter are not significantly different at the 95% probability level by the Waller-Duncan k-ratio test, a = 0.05.

	Yield ($\times 10^{-2} m^3$ / tree)	**Yield (m^3 / ha)**
103	2.55 ab	40.4 abcd
104	3.55 a	51.8 ab
105	3.18 abc	49.9 ab
110	1.92 cde	29.4 cd
111	2.32 abcde	34.4 abcd
117	3.47 ab	52.5 a
118	2.85 abcd	38.8 abcd
122	2.33 abcde	33.8 abcd
123	2.91 abcd	43.9 abc
124	2.17 bcde	30.5 bcd
125	1.88 cde	30.2 bcd
159	1.59 de	22.2 cd
169	1.46 e	20.0 d
Mean	2.48	36.4
SE	0.14	3.0
PR > F	0.0036	0.0043
$MSD_{0.05}$	1.33	21.9

Seed Orchards

The first seed orchards, and the only ones known to exist in the native range of *C. longissima*, are located at Roche Blanche, Haut Camp and Terrier Rouge. Orchards were also established at Marmont and Bombardopolis, but were discontinued because of problems associated with the site conditions and management.

The Roche Blanche orchard is the largest and best developed, comprising of 51 family collections and 3 bulk collections. The broad genetic base of the orchard is important because it leaves options open for various breeding strategies and ensures genetic diversity for unforseen problems in the future, particularly those relating to drastically altered habitats, pests and diseases. Furthermore, the orchard play a fundamental role as clone banks, since every genotype that exhibits superior traits in the progeny trials can be located and reproduced vegetatively at some future time. Many of the plus trees that were selected have been harvested and are no longer available as germ plasm sources, making the orchard the only source of genetic material for future propagation. The economic impact of improved genetic material multiplied by several thousand Haitian farmers justifies the costs of orchard investments.

The Roche Blanche orchard began producing seed during the first year after planting. Seed harvests for forestry nurseries began during the third year. Seed collected from the orchard should be considered open-pollinated and outcrossed with neighboring families. In order to state with confidence that seed from the selected families in the orchard is improved material, genetic tests should be continued with progeny of the orchard families.

The Haut Camp and Terrier Rouge orchards comprise 22 and 21 families, respectively. *C. longissima* has not developed as quickly at Haut Camp because of the extremely shallow and rocky soils or at Terrier Rouge because of the sub-humid site conditions. However, the land is relatively secure and more intensive management of the orchards is feasible if sufficient seed demand merits the additional costs of upgrading and optimizing conditions for seed production.

CONCLUSIONS

C. longissima is an economically important native species and one of the most sought after woods in Haiti. The seed orchards and trials reported here represent a valuable resource for perpetuating the species in Haiti and providing income to farmers. The orchards contain the broadest genetic base of the species in its native range and have the best chance to date of producing a seed mix that is broadly adapted for providing superior genetic material to small farmers.

Significant genetic variations were found in *C. longissima* for merchantable wood volume. Less important differences were also found for height and stem diameter growth. Although the superior genotypes may be reproduced vegetatively, we do not have sufficient information to recommend with confidence specific genotypes as an improved seed source across a range of site conditions. However, we now know that improvements in productivity are possible and that variability exists in the present trials and orchards from which these improvements can be made. Because of the economic importance of this species, a program of genetic improvement, combined with seedling distribution and training, should yield economic returns.

The logical next step in the process of tree improvement is to conserve the genetic combinations that yield the highest returns of merchantable lumber through vegetative propagation. The resultant clones may be used directly at the farm level or in additional seed orchards. One option for PLUS is to distribute a package of improved genetic material and improved silvicultural practices to as many farmers as possible, but targeting farming groups that already exploit or manage the species as a significant source of income. A comparative approach should be used that would allow farmers to prove to themselves the gains that can be achieved. Local checks (i.e., controls) would be fundamental to establish with any degree of certainty the magnitude of genetic gain that can be expected during the first rotation. Once this gain is confirmed from the perspective of the farmer, additional constraints in improving profits should be addressed by PLUS. These limitations might include tree tenure and security, transport and marketing constraints, investment opportunities in value-added enterprises, and so on.

Production and sale of certified seed from the orchards is another opportunity that should be explored, particularly for expanded markets abroad.

Although USAID has currently stopped further investments in the genetic conservation and improvement of Haitian tree species, efforts should be made to preserve past investments, particularly in face of an ever-changing environment and economy. The government of Haiti should focus on issues that support the proper stewardship of Haiti's forests as a renewable resource. *C. longissima* is part of an exploited natural resource base that must be conserved through continued investment in both genetic conservation and improvement with seed orchards and progeny testing.

RECOMMENDATIONS

Immediate recommendations follow that would be implemented in logical progression of managing *C. longissima* as a native tree species of economic importance.

(1) **Producer Groups.** In order to guarantee the best performance at the level of the small farmer, PLUS should target most of the improved germplasm to farmers with sites where *C. longissima* grows best and is already integrated into local agroforestry systems – the agricultural plains and ravines. Producer groups that derive a significant source of their income from the harvest of *C. longissima* lumber are the most likely to pay the price of improved genetic material.

(2) **Role of Government.** Collaborate with the Ministry of Agriculture in seeking funds for genetic conservation and improvement of economically important tree species. Discuss long term strategy and short term benefits that include certified seed production, seed export and marketing, public and private sector forestry investment, forest genetic resource policy and extension education. Determine incentives and enforce policy that encourages farmers to manage tree crops. *C. longissima* can serve as a model species upon which such a program can be developed.

(3) **Species Awareness.** A system needs to be put in place for production, distribution and marketing of Haitian oak. The *C. longissima* seed orchards and progeny trials are currently managed as well as can be expected by landowners not trained in forestry, particularly forest genetics. If any long-term improvements are to be sustained with the species, it is critical that the orchards and progeny testing be managed by trained individuals committed to such purposes. Seed production from the orchards should not be overlooked as a commercial product to be marketed through seed companies or directly to nurseries worldwide.

(4) **Tree Improvement.** The existing orchards and trials should form the basis of a seed production and distribution to farmers in Haiti. They contain the broadest genetic base of the species in its native range and have the best chance to date of producing a seed mix that is broadly adapted, while delivering superior genetic material to the small farmer.

(5) Improved seed from the orchards should be channelled to farmers through an efficient production of containerized seedlings. This is the most effective way to distribute improved genetic material at a national scale and one of the strongest arguments to continue the subsidized production of seedlings for reforestation. The goal of every tree nursery in Haiti should be to propagate trees with the best genetic material available. Too often, the pressure on projects to be efficient leads to rushed planting schedules and mass tree quantities with a resulting sacrifice in genetic quality. This only hinders economic development for many decades down the road.

(6) **Tree Management.** Information on vegetative propagation procedures should be disseminated along with improved genetic material to farmer groups who understand the management of *C. longissima*. Vegetative propagation is the most effective approach to capture genetic gain and regenerate the species for commercial purposes. However, the technology must be communicated effectively to farmers and must be accompanied by access to the best available genetic material. Maintenance of the orchards and progeny trials is necessary in order to provide a secure source of superior genotypes for genetic propagation at the farmer level.

(7) **Long Term Adaptability.** The progeny trials should be monitored for disease resistance, pests, tree form and other parameters that effect its potential economic impact to Haitian farmers for at least half the time required to produce lumber. The differences among *C. longissima* genotypes, as expressed above in percentages, are likely to decrease in magnitude simply because the wood volumes being compared are larger. The final analysis should be in terms of market values and should be based on actual recovery volumes. Selections in the progeny trials can be at both the individual and family levels to improve the genetic quality of seed produced from the trial for second generation production. This seed should be well-adapted to comparable site conditions of the region where the trial is located.

(8) **Applied Research.** Determine ways that Haitian farmers select, propagate and manage *C. longissima* as an asset. Study improved silvicultural practices (propagation, thinning, pruning and harvesting) of *C. longissima* specific to the major agroforestry models (i.e., wood lots, boundary plantings, shade trees) in Haiti.

(9) Develop volume tables for a larger diameter range than that determined for the species by Ehrlich et al. (1986). These tables are an important management tool, allowing for an accurate estimation of volume at both the individual and stand levels. These tables are useful tools for thinning and harvest schedules, genotype means comparisons, and economic analyses. Determine the economic role of the species in Haiti on a periodic basis.

10) Study phenology and pollination biology of species for breeding and selection strategies. Determine the conservation status of the species on a periodic basis.

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Annex 1. Information on the *C. longissima* plus tree candidates selected in Haiti (1988–1989). Mother tree and family numbers are the same.

FAMILY NO.	LOCATION	ELEV. (m)	LATITUDE	LONGITUDE	DBH (cm)	TOTAL HEIGHT (m)	STEM HEIGHT (m)	CROWN WIDTH (m)
102	Km 70, Jacmel	360	18º 18' N	72º 34' W	22.5	14.6	9.6	3.6
103	Diclo, Km 50, Léogâne	440	18º 23' N	72º 30' W	25.7	11.4	8.0	4.3
104	Diclo, Km 50, Léogâne	440	18º 23' N	72º 30' W	24.0	11.6	8.6	5.7
105	L'Acul, Km 42, Léogâne	25	18º 26' N	72º 40' W	40.5	22.0	11.0	6.7
106	L'Acul, Km 42, Léogâne	25	18º 26' N	72º 40' W	32.2	21.5	13.6	5.7
107	L'Acul, Km 42, Léogâne	25	18º 26' N	72º 40' W	36.5	20.6	12.0	4.8
108	Bas Tapion, Grand-Goâve	10	18º 25' N	72º 46' W	23.0	18.5	NA	NA
109	Fontabi, Petit-Goâve	10	18º 25' N	72º 46' W	38.0	19.4	13.8	8.5
110	Dlo Rele, Grand-Goâve	180	18º 25' N	72º 47' W	21.5	17.8	11.9	4.7
111	Ti Paradis, Grand-Goâve	15	18º 25' N	72º 45' W	36.0	23.4	12.0	3.8
112	Gesom, Petit-Goâve	800	18º 18' N	72º 42' W	25.9	14.0	7.0	4.9
114	Vinier, Arcahaie	25	18º 45' N	72º 28' W	40.0	19.0	16.0	NA
115	Guillaume, Arcahaie	16	18º 47' N	72º 31' W	35.0	21.5	16.0	NA
116	Band du Nord, Cap Haïtien	60	19º 47' N	72º 12' W	66.6	22.8	9.6	13.1
117	Vinier, Arcahaie	100	18º 46' N	72º 28' W	36.5	24.5	16.0	NA
118	Vaudreuil, Cap-Haïtien	30	19º 42' N	72º 15' W	49.5	23.9	12.6	NA
119	Modieu, Limbé	110	19º 41' N	72º 24' W	31.0	22.6	8.8	6.5
120	Thomonde, Hinche	300	19º 00' N	71º 57' W	39.0	20.0	11.6	7.8
121	Deklero, Quartier Morin	25	19º 41' N	72º 10' W	61.5	26.0	7.2	14.0
122	Deklero, Quartier Morin	25	19º 41' N	72º 10' W	52.0	27.6	11.7	12.0
123	Labordette, Petit-Goâve	450	18º 23' N	73º 12' W	23.5	16.4	9.2	4.0
124	Charlier, Pte Riv. De Nippes	10	18º 29' N	73º 11' W	NA	NA	NA	NA
125	Charlier, Pte Riv. De Nippes	10	18º 29' N	73º 11' W	NA	NA	NA	NA
127	Anons, Jérémie	100	18º 33' N	74º 06' W	22.5	15.4	12.4	2.6
128	Band du Nord, Cap Haïtien	90	19º 47' N	72º 12' W	NA	NA	NA	NA
129	Gamel, Cap-Haïtien	50	19º 46' N	72º 25' W	41.0	23.4	11.8	6.6
131	Bake, Mirebalais	200	18º 47' N	72º 02' W	38.6	26.0	18.0	7.0
132	Manzè Mari, Jacmel	240	18º 15' N	72º 44' W	29.5	22.0	17.5	6.5
134	Thomonde	280	19º 00' N	71º 57' W	37.0	17.5	14.0	7.4
136	Savane Calebasse, Lascahobas	205	18º 56' N	71º 55' W	31.2	20.1	17.6	5.0
137	Limbé	40	19º 42' N	72º 24' W	36.0	25.0	14.4	6.0
138	Limbé	40	19º 42' N	72º 24' W	NA	NA	NA	NA
139	Savane Longue, Ouanaminthe	90	19º 31' N	71º 45' W	38.5	19.2	12.2	8.4
140	Savane Longue, Ouanaminthe	90	19º 31' N	71º 45' W	36.0	16.8	9.4	7.0
143	Fauché, Port Margot	55	19º 44' N	72º 25' W	NA	24.6	11.2	11.0
146	L'Acul, Léogane	5	18º 26' N	72º 40' W	32.2	21.5	13.6	5.7
148	Ca Charlier, Charlier	15	18º 29' N	73º 12' W	18.0	13.0	10.5	3.4
149	Félisian, Lascahobas	200	8º 55' N	71º 51' W	25.0	15.8	12.5	4.0
150	Fontabi, Petit Goâve	40	18º 25' N	72º 58' W	47.0	25.5	15.3	7.2
151	Fontabi, Petit Goâve	40	18º 25' N	72º 58' W	38.0	24.9	20.1	6.3
155	Ravine Pac, Petit Goâve	165	18º 16' N	72º 57' W	32.3	19.0	12.6	4.6
158	Kalompre, Trouin	540	18º 21' N	72º 41' W	37.3	16.6	6.2	6.4
159	Thomonde	280	19º 00' N	71º 57' W	28.1	25.0	10.0	7.5
160	Dampuce, Grand-Goâve	65	18º 24' N	72º 42' W	34.0	15.8	12.5	4.8
161	Félisian, Lascahobas	190	18º 55' N	71º 55' W	34.5	NA	NA	6.4
163	2ème Plaine, Petit-Goâve	55	18º 24' N	71º 01' W	33.5	21.0	11.0	6.1
169	Labordette, Petit-Goâve	450	18º 23' N	73º 12' W	22.0	20.0	14.0	NA
174	Jean Rabel	65	19º 51' N	73º 12' W	32.0	19.0	8.0	6.1
177	Valoi, Jean Rabel	240	19º 51' N	73º 10' W	33.0	25.0	21.6	5.5
178	Fonds Begle, Bombardopolis	465	18º 50' N	73º 35' W	47.5	16.0	13.0	9.8
181	Labordette, Petit Goâve	400	18º 23' N	73º 12' W	NA	NA	NA	NA
185	Savane Longue, Ouanaminthe	90	19º 31' N	71º 45' W	25.0	14.8	10.8	4.3188
188	Coplo, Ouanaminthe	75	19º 30' N	71º 46' W	23.0	16.8	11.6	3.8
	Mean	157.6			34.3	19.9	12.3	6.4
	Std. Dev.	175.2			10.1	4.1	3.3	2.5
	Max.	800			66.6	27.6	21.6	14.0
	Min.	5			18.0	11.4	6.2	2.6

Annex 2. Survival means of *C. longissima* families at the progeny trials and orchards in Haiti.. Means followed by the same letter are not significantly different, according to Waller-Duncan k-ratio Test, a = 0.05, of the arcsine transformed data.

	PROGENY TRIALS								SEED ORCHARDS										
FAM. NO.	CROCRA			LABORDE			LAPILA		HAUT CAMP			ROCHE BLANCHE 1			ROCHE BL. 2		TERRIER ROUGE	
	12 m	36 m	60 m	12 m	36 m	60 m	12 m	60 m	12 m	36 m	60 m	12 m	36 m	60 m	12m	36m	36 m	60 m
	%																	
102															100	75	83	83
103				100 a	100 a	100 a	93 abc	85 abc	100	100	91	90	80	80			50	44
104				100 a	100 a	98 a	96 abc	91 abc	100	100	100	100	100	100			72	67
105	96 a	91 a	89 a	100 a	100 a	100 a	93 abc	87 abc	95	95	76	100	100	100			50	50
106							100 a	96 ab	100	100	95	90	90	90				
107							94 abc	89 abc	100	100	91	90	90	90	100	100	89	89
108							93 abc	87 abc	100	100	91	90	90	90				
109							92 abc	83 c	95	95	95				89	78		
110				94 b	94 b	92 a	89 c	83 c	100	100	86	90	90	80				
111				98 ab	98 ab	98 a	96 abc	87 bc	100	100	100	80	80	80				
112															88	88	56	56
114									100	100	95	80	80	80	100	100	67	67
115															100	83	67	67
116	96 a	91 a	79 a												100	78		
117	94 a	91 a		100 a	100 a	98 a	94 abc	91 abc	100	100	100	100	100	100			61	50
118				98 ab	98 ab	98 a	93 abc	89 abc	100	95	95	70	70	70				
119									100	95	95				100	100	61	56
120	94 a	93 a	89 a				96 abc	91 abc	91	86	86	90	90	90				
121							100 a	96 ab	100	100	95	80	80	80				
122				100 a	100 a	100 a	93 abc	87 abc	100	95	86				100	88	56	50
123				100 a	100 a	100 a	100 a	96 ab	91	91	91	90	90	90				
124				100 a	100 a	98 a	85 bc	78 c	100	100	95	80	80	80				
125				100 a	100 a	100 a	94 abc	89 abc	100	100	85	100	100	100				
127							96 abc	91 abc	100	95	86				88	63		
128	94 a	94 a	91 a												100	100		
129															100	75	83	72
131							57 d	54 d							100	88	61	56
132	96 a	88 a	86 a				59 d	56 d							100	100	67	61
134															100	100	50	50
136	96 a	94 a	94 a												100	100		
137																		
138															89	56	67	56
139							100 a	98 a										
140															100	71		
143															100	100		
146							65 d	61 d							88	75		
148															88	88		
149							98 ab	89 abc							100	75		
150															100	88		
151															100	100		
155															100	89		
158															100	71		
159				98 ab	98 ab	96 a			100	95	86	70	70	70				
160	92 a	85 a	81 a												100	78	67	56
161															100	78	67	67
163															100	100	67	61
169				98 ab	98 ab	96 a			91	91	86	100	100	100				
174															100	78	61	39
177															86	86		
178															100	86	78	67
181															88	88		
185															100	75		
188															78	78		
Mean	95.0	90.8	87.0	99.0	98.8	97.8	90.3	84.9	98.5	97.0	91.2	88.3	87.8	87.2	96.6	85.0	65.7	60.2
SE	1.1	1.8	2.2	0.4	0.4	0.6	1.2	1.4	0.7	0.8	1.3	2.3	2.4	2.4	1.0	2.0	2.4	2.6
Pr >F	0.94	0.95	0.82	0.35	0.35	0.35	0.0001	0.0001										

Annex 3. Total height means of *C. longissima* families at the progeny trials and orchards in Haiti. Means followed by the same letter are not significantly different, according to Waller-Duncan k-ratio Test, a = 0.05.

	PROGENY TRIALS								SEED ORCHARDS									
FAM. NO.	CROCRA			LABORDE			LAPILA		HAUT CAMP			ROCHE BLANCHE 1			ROCHE BL. 2		TERRIER ROUGE	
	12 m	36 m	60 m	12 m	36 m	60 m	12 m	60 m	12 m	36 m	60 m	12 m	36 m	60 m	12 m	36 m	36 m	60 m
	------------------------------ m ------------------------------																	
102															0.5ab	1.42a	2.1a	2.9ab
103				1.1abcd	4.2a	5.9a	0.6defg	1.6abc	0.6ab	1.2a	2.1a	2.2a	5.3a	6.6a			2.0a	2.5ab
104				1.1abcd	4.4a	6.8a	0.6fgh	1.9abc	0.5b	1.0a	1.5a	2.0a	5.1a	6.2a			2.4a	3.1ab
105	0.7a	2.2a	2.7a	1.2abc	4.7a	6.4a	0.6bcdef	1.4c	0.6ab	1.1a	0.9a	2.0a	5.2a	6.6a			1.9a	2.3abc
106							0.6bcde	1.6abc	0.6ab	1.0a	1.2a	1.8a	4.6a	5.9a				
107							0.7abc	1.5bc	0.7ab	1.2a	1.4a	1.9a	5.1a	6.2a	0.5abc	1.26a	2.2a	2.9abc
108							0.6bcde	1.4c	0.5b	1.3a	2.2a	1.8a	4.6a	5.5a				
109							0.6cdef	1.3c	0.5ab	1.3a	1.2a				0.5abc	1.29a		
110				1.0bcd	4.0a	5.9a	0.5ij	1.4bc	0.5b	1.1a	1.7a	1.9a	4.4a	5.7a				
111				1.1abcd	4.1a	6.3a	0.5ghi	1.3c	0.5b	1.3a	1.6a	1.8a	4.7a	6.1a				
112															0.5abcd	1.10a	1.8a	2.2abc
114									0.6ab	1.1a	1.3a	2.0a	5.0a	5.9a	0.5abc	1.40 a	1.9a2.	
115															0.4bcd	1.10a	1.8a	2.5abc
116	0.8a	2.2a	2.7a												0.5abcd	1.18a		
117	0.7a	2.1a	2.6a	1.2abcd	4.4a	6.7a	0.7ab	1.7abc	0.7ab	1.2a	1.6a	2.0a	4.9a	6.3a			2.0a	2.3abc
118				1.2ab	4.5a	6.4a	0.6bcd	1.8abc	0.6ab	1.1a	1.3a	2.0a	4.9a	5.7a				
119									0.6ab	1.0a	1.4a				0.5ab	1.08a	2.2a	2.8abc
120	0.8a	2.9a	2.8a				0.6bcd	1.8abc	0.6ab	1.3a	1.9a	2.2a	4.8a	5.3a				
121							0.7ab	1.8abc	0.5b	1.0a	1.1a	2.1a	4.9a	5.8a				
122				1.1abcd	4.1a	5.8a	0.6cdef	1.5abc	0.5ab	1.2a	1.5a				0.5abcd	1.20a	1.5a	
123				1.3a	4.7a	6.4a	0.6bcdef	1.5abc	0.8a	1.2a	1.5a	2.0a	5.2a	6.2a				
124				1.3a	4.4a	5.9a	0.7ab	1.7abc	0.7ab	1.3a	1.8a	2.3a	5.3a	6.1a				
125				1.3a	4.3a	5.7a	0.6efg	2.1ab	0.5ab	1.1a	1.5a	1.8a	4.3a	5.5a				
127							0.5hij	1.5abc	0.5b	0.9a	1.4a				0.4abcd	0.84a		
128	0.8a	2.3a	2.6a												0.5abcd	1.30a		
129															0.5ab	1.23a	1.7a	2.7abc
131							0.4k	1.9abc							0.5abcd	1.21a	1.8a2.	
132	0.8a	2.4a	3.0a				0.5ij	1.8abc							0.4abcd	1.03a	1.5a2.	
134															0.5ab	1.08a	2.0a	2.7abc
136	0.8a	2.4a	2.5a												0.5abc	1.54a		
137																		
138															0.4abcd	1.56a	2.2a2.	
139							0.6bcde	1.7abc										
140															0.4abcd	1.26a		
143															0.4bcd	1.20a		
146							0.4jk	1.4c							0.3cd	1.23a		
148															0.4abcd	1.19a		
149							0.7a	2.2a							0.3d	1.06a		
150															0.4abcd	1.10a		
151															0.6a	1.10a		
155															0.5abcd	1.39a		
158															0.5abc	1.44a		
159				0.9d	3.8a	5.3a			0.6ab	1.4a	2.0a	1.9a	4.1a	4.8a				
160	0.8a	2.5a	2.8a												0.4abcd	1.30a	2.2a3.	
161															0.5abc	1.47a	1.7a	2.3abc
163															0.4abcd	1.29a	1.9a2.	
169				1.0cd	3.8a	5.4a			0.5b	1.1a	1.4a	2.2a	5.3a	6.2a				
174															0.4abcd	1.17a	1.6a2.	
177															0.5abc	0.98a		
178															0.4abcd	1.08a	1.7a2.	
181															0.4abcd	1.09a		
185															0.5ab	1.31a		
188															0.5abc	1.35a		
Mean	0.77	2.37	2.73	1.13	4.24	6.06	0.59	1.64	0.58	1.14	1.54	1.99	4.87	5.94	0.45	1.23	1.92	2.57
SE	0.02	0.09	0.11	0.03	0.09	0.12	0.81	0.04	0.02	0.03	0.07	0.04	0.08	0.11	0.01	0.03	0.05	0.08
Pr >F	0.15	0.38	0.94	0.008	0.47	0.11	0.0001	0.013	0.03	0.19	0.18	0.64	0.50	0.54	0.003	0.488	0.18	0.06
MSD	0.20	–	–	0.24	–	1.55	0.07	0.68	0.21	0.53	1.34	0.96	1.96	2.51	0.21	1.04	0.99	1.20

Annex 4. Dbh and $D_{0.1}$ means of the *C. longissima* families in Haiti. Means followed by the same letter are not significantly different, according to Waller-Duncan k-ratio Test, a = 0.05.

	PROGENY TRIALS							SEED ORCHARDS							
FAM. NO.	CROCRA DBH 36 m	CROCRA DBH 60 m	CROCRA $D_{0.1}$ 60 m	LABORDE DBH 36 m	LABORDE DBH 60 m	LABORDE $D_{0.1}$ 60 m	LAPILA DBH 60 m	HAUT CAMP DBH 36 m	HAUT CAMP DBH 60 m	HAUT CAMP $D_{0.1}$ 60 m	R. BL. 1 DBH 36 m	R. BL. 1 DBH 60 m	TERRIER ROUGE DBH 36 m	TERRIER ROUGE DBH 60 m	TERRIER ROUGE $D_{0.1}$ 60 m
	---------- cm ----------														
102													1.5 a	3.4	6.4abc
103				6.0ab	8.0a	10.9ab	1.6abc	0.9 bc	3.6ab	5.9ab	8.9 a	13.8 a	2.0 a	2.5 bc	5.2bcd
104				6.1ab	8.4a	11.9a	1.9abc	1.8	1.5b	4.8ab	7.7 ab	12.0 ab	2.0 a	3.5	
105	2.0 a	3.4 a	5.2 a	6.3a	8.5a	11.7ab	1.4c	0.8 bc	–	–	8.2 ab	12.6 a	1.5 a	2.7 bc	
106							1.6abc	0.7 bc	1.8b	4.5ab	6.3 ab	10.0 ab			
107							1.5bc	1.1 bc	1.4b	4.5ab	8.0 ab	11.9 ab	2.1 a	3.4	
108							1.4c	2.7 a	5.4a	8.0a	7.1 ab	11.0 ab			
109							1.3c	0.8 bc	1.9b	4.7ab					
110				5.6ab	8.1a	11.2ab	1.4bc	0.8 bc	2.4ab	5.7ab	6.5 ab	10.9 ab			
111				5.6ab	8.1a	11.4ab	1.3c	0.9 bc	2.0b	4.9ab	6.9 ab	11.5 ab			
112													1.2 a	2.5 bc	4.4d
114								1.2	2.2ab	4.9ab	8.3 ab	10.4 ab	1.5		
115													1.4 a	3.2	5.7abcd
116	1.9 a	3.8 a	5.5 a												
117	1.8 a	3.2 a	5.2 a	5.9ab	8.4a	10.9ab	1.7abc	0.6 bc	1.3b	4.4b	7.5 ab	10.2 ab	1.8 a	3.3	
118				5.8ab	8.5a	11.4ab	1.8abc	0.5 c	1.1b	4.0b	7.0 ab	10.7 ab			
119								0.8 bc	1.5b	4.3b			1.5 a	3.3	5.7abcd
120	2.2 a	3.5 a	5.6 a				1.8abc	0.9 bc	1.8b	4.9ab	7.3 ab	9.7 ab			
121							1.8abc	0.8 bc	1.1b	4.1b	7.6 ab	11.5 ab			
122				5.6ab	8.2a	11.1ab	1.5abc	1.1 bc	1.3b	4.9ab			1.9 a	1.8 c	4.9cd
123				6.3a	8.5a	11.7a	1.5abc	0.9 bc	1.8b	4.3b	7.6 ab	11.3 ab			
124				6.0ab	7.7a	10.5ab	1.7abc	2.0 ab	4.0ab	6.3ab	7.9 ab	11.4 ab			
125				5.7ab	7.3a	10.4ab	2.1ab	1.5	3.8ab	6.1ab	5.7 b	10.6 ab			
127							1.5abc	1.5 abc	2.5ab	5.5ab					
128	2.0 a	3.4 a	5.4 a												
129													1.7 a	3.4	5.8abcd
131							1.9abc						1.3 a	3.3	5.7abcd
132	2.0 a	3.6 a	6.0 a				1.8abc						0.9 a	2.1 c	4.6cd
134													1.3 a	3.0	5.2bcd
136	2.0 a	3.3 a	5.0 a												
137															
138													1.9 a	4.3 ab	6.8ab
139							1.7abc								
140															
143															
146							1.4c								
148															
149							2.2a								
150															
151															
155															
158															
159				4.6b	6.8a	9.7ab		1.2	2.8ab	5.7ab	6.6 ab	7.8 b			
160	2.3 a	3.2 a	5.3 a										2.4 a	4.9 a	7.4a
161													1.2 a	2.3 c	4.5cd
163													2.0 a	2.5 bc	4.7cd
169				4.8ab	6.4a	9.1b		1.2	1.4b	4.3b	8.6 ab	12.6 a			
174													1.4 a	2.9 bc	5.8abcd
177															
178													1.5 a	3.0 bc	6.0abcd
181															
185															
188															
Mean	2.05	3.43	5.46	5.71	7.91	10.92	1.61	1.11	2.21	5.09	7.41	11.11	1.63	3.07	5.57
SE	0.12	0.17	0.17	0.14	0.18	0.21	0.09	0.11	0.25	0.13	0.20	0.31	0.08	0.16	0.16
Pr >F	0.74	0.71	0.34	0.11	0.15	0.11	0.10	0.18	0.031	0.10	0.10	0.15	0.29	0.03	0.01
MSD	–	–	–	1.66	2.30	2.61	1.97	1.34	3.34	3.48	2.93	4.77	1.83	1.92	1.83